

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

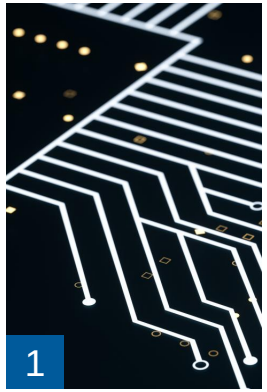
deftech.ch

Technische Hochschule Ingolstadt
Bayerisches Foresight-Institut

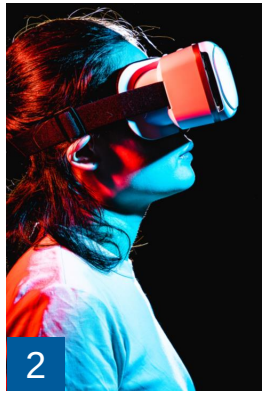
AnticipaTech Scenario Game

Trendbook

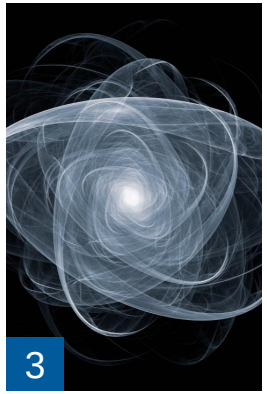
Technological trends overview



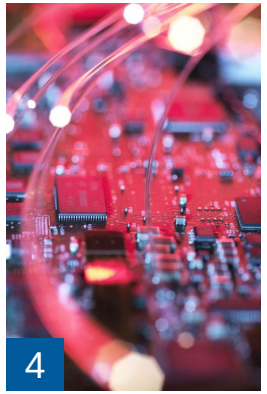
Data science and AI



Immersive technologies



Quantum technologies



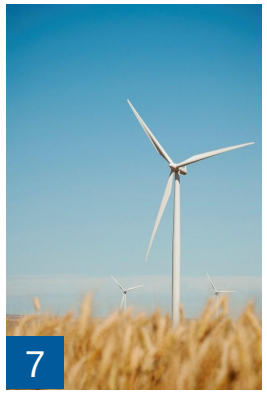
Sensor technologies



New space technologies



New materials and digital production



Green energy and resilience



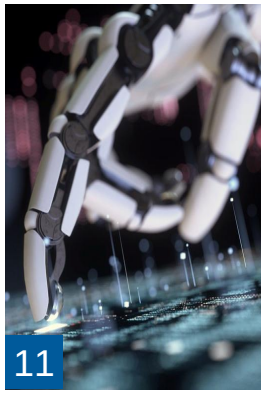
Human enhancement technologies



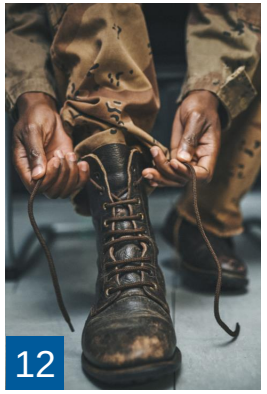
Cyber technologies



Digital communication



Robotic and autonomous systems



New weapons

Data Science & AI

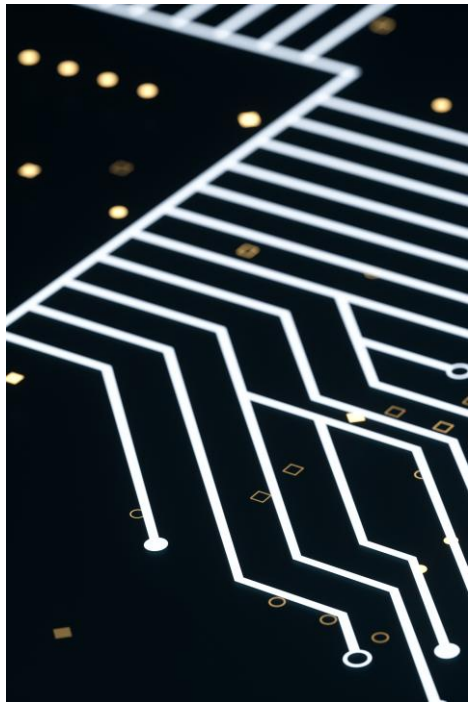
Technological trend 1 – Harnessing the power of data to emulate and overcome human intelligence

Description

Advanced (data) analytics describes advanced analytical methods for making sense of and visualising large volumes of information. **Artificial Intelligence (AI)** refers to the ability of machines to perform tasks that normally require human intelligence.

Data analytics methods can extract insights, classifications, and predictions, from large, potentially unstructured data sets. **AI functions** can be broken down to **parsing inputs** (e.g. perception, natural language processing, taking cues from social intelligence), and **planning as well as executing outputs ('behaviour')** (e.g. knowledge representation, prioritisation, and planning). **Machine learning**, a subfield of AI, aims to create algorithms that can automatically learn the relationship between input data and desired outcomes, like classifications or actions.

This trend is driven by the increasing digitalisation of all aspects of life, and by massive commercial investments.



Key uncertainties

How can we deal with the lack of interpretability of current AI algorithms? How will current AI models be able to scale towards more advanced capabilities? How will data ownership and rights, as well as further development of AI models be regulated?

Relevance / Impact

- Economic productivity gains resulting from the automation of tasks and enhancement of labour force.
- Consumer demand increases due to enabling of personalised products and increased leisure time.
- Effect of integrating AI into daily life (e.g. chatbots, virtual assistants) on human-computer interaction and social dynamics.

Weak Signals (Proofs / Examples)

- Researchers introduce technology enabling deep learning model training on edge devices like mobile phones.
- Researchers utilise AI to accurately recognise and classify animal social behaviour.
- Startup devises predictive analytics solution, utilising data to cut freight costs by optimising transport routes, considering factors like weather, tides, and wind speed.

Technological maturity



High

Immersive technologies

Technological trend 2 – Merging the physical and the virtual world to transform experiences

Description

Immersive technologies can enable a deeply engaging, multisensory, digital experience. **Augmented reality (AR)** overlays digitally created content into the user's real-world environment. **Virtual reality (VR)** creates a fully rendered digital environment that replaces the user's real-world environment.

Immersive technologies are used in various ways. In **product design and development**, they give immediate access to important information at every stage. For **collaboration and cooperation**, they help to engage with, to share information, and support colleagues in different locations. In **learning and training**, they allow trainees to experience realistic situations that are hard to recreate in real life. They also **enhance consumer experiences** by bringing potential customers closer to products and services.

This trend is driven by increased use of smart devices, increase in connectivity, and the need for remote work.



Key uncertainties

Will immersive technology ideas remain at the proof of concept stage or begin to break through to scale? Are business models to support future applications viable? How can novel forms of harm, scams, and crime be enabled by augmented reality? What will be the effect of immersive technologies on the nature of work?

Relevance / Impact

- Using immersive technologies in industrial settings, the production process can be improved through early-warning-detection mechanisms, improved quality assurance, and rapid prototyping.
- Immersive technology-assisted products and services can engage consumers in new ways and increase sales and consumption.
- Immersive training for search and rescue could build "muscle memory" for real-life situations.

Weak Signals (Proofs / Examples)

- Fast food firm trains employees by placing them in a virtual "escape room" where they must successfully complete a five-step chicken preparation process before they are released.
- Startup aims to establish a metaverse-based "educational city" for students from grades 1 to 12.
- Researchers introduce tools to safeguard bystander privacy in real-time sensor data, by employing eye tracking, near-field microphones, and spatial awareness.

Technological maturity



Intermediate

Quantum technologies

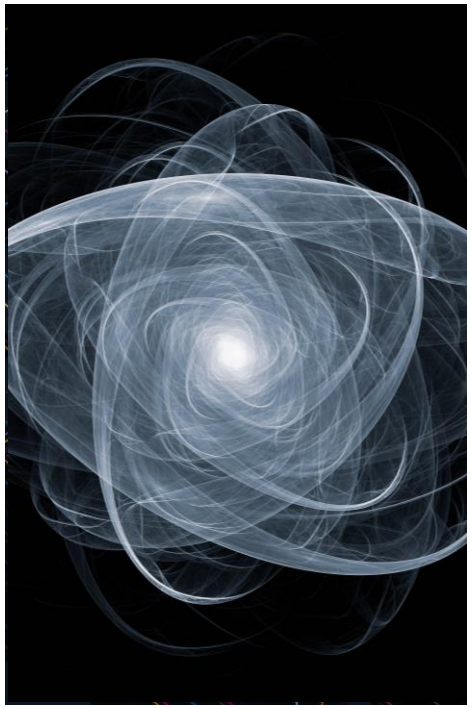
Technological trend 3 – Using quantum physics to create "magical" devices

Description

Quantum technologies harness quantum phenomena like entanglement and superposition, offering capabilities surpassing classical devices. Quantum technologies span quantum sensing, communication, and computing.

Quantum sensing increases the accuracy in measuring time, acceleration, magnetic fields, and electromagnetic radiation. This is crucial for navigating without GPS and improving reconnaissance (scouting of an area). **Quantum communication** uses the quantum properties of light to enhance security and to detect eavesdropping on communications. It also enables to connect quantum sensors and computers in a network. **Quantum computing** provides more computational power for encryption/decryption, optimisation, and simulations. This could render current encryption methods outdated and help create new materials through simulations.

Technological advancements in the relevant areas, as well as commercial and military interests, drive this trend.



Key uncertainties

How can the daunting technical challenges be overcome? How can the relatively narrow application scope be expanded, especially for quantum computing? How does "quantum decryption" affect privacy concerns?

Relevance / Impact

- Enhanced sensitivity in sensing for time, acceleration, magnetic fields, electromagnetic radiation, enables "magical" remote sensing and navigation capabilities.
- Increased security and eavesdropping detection using the quantum properties of light.
- Orders of magnitude improved computational performance for specific problems (encryption, optimisation, simulation).

Weak Signals (Proofs / Examples)

- Consortium collaborates on quantum technology to improve flood risk assessment, overcoming computational limitations.
- Startup unveils cloud-native service for executing conventional and quantum algorithms, simplifying development and accessibility.
- Researchers develop a high-rate photon detector, potentially revolutionising high-speed quantum communication by measuring individual photons.

Technological maturity



Low

Sensor technologies

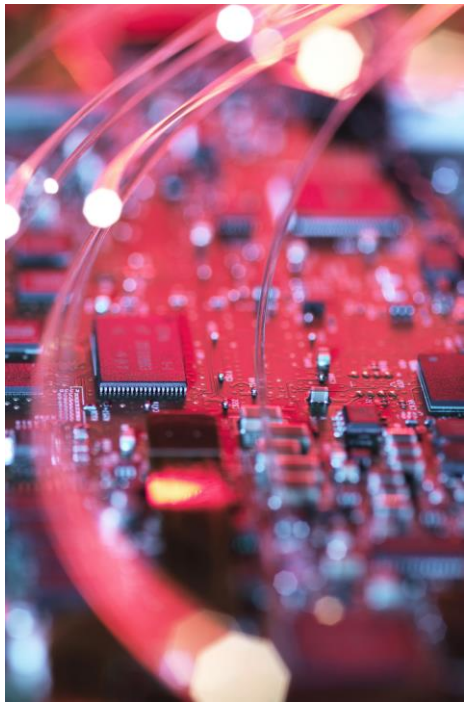
Technological trend 4 – Capturing data for smarter decisions and to enhance life's efficiency

Description

A **sensor** converts a physical measure into a signal that is read by an observer or by an instrument. Sensor technologies are advancing along three general paths of improvement: **enhanced sensing performance**, **miniaturisation** and **distribution**. Several advanced sensor technologies offer improvements along one or more of these paths.

MEMS sensors have been the main contributor to the change in scale and functionality of sensors over the last decade. **Nanosensors** take advantage of the unique properties of nanoscale materials. **Flexible sensors** can withstand mechanical deformation. **Bioinspired sensors** take inspiration from basic concepts behind sensory physiology. **Lab-on-chip sensors** can perform various complex laboratory operations on a miniaturised scale. **Smart dust** is comprised of many dust-sized smart sensors.

Advancements in sensor technologies are driven by the increasing performance and cost demands of other sectors.



Key uncertainties

How will sensor performance and miniaturisation evolve? How will the secondary capabilities of smart sensors (power, communications, computing) evolve? Will novel sensor technologies be able to be produced and deployed in scale? What new data-based business models could emerge based on novel sensors?

Relevance / Impact

- Sensor technologies are enabling performance, miniaturisation, and connectivity to achieve a huge impact in many sectors (e.g. consumer electronics, automotive, manufacturing).
- The vast amount of data collected can feed into a “data economy”, producing value for many stakeholders.
- Sensors can make technology personal, by being included in many everyday objects.

Weak Signals (Proofs / Examples)

- Researchers create a method for mass-producing graphene-based sensors that detect lead, mercury, and E. coli in water.
- Researchers devise gravimetric sensors to detect greenhouse gases like carbon dioxide and methane, offering greater sensitivity and lower energy consumption than electrochemical sensors.
- Space data company about to employ hyperspectral imaging to assist precision farming.

Technological maturity



Intermediate

New Space technologies

Technological trend 5 – Space Race 2.0, the next giant leap for humankind

Description

Space technologies make use of the unique conditions of space, but also must deal with the challenges that come with operating there.

Within the next years to a decade, space can enable groundbreaking applications such as navigation for autonomous vehicles, real-time Earth imaging for advanced agriculture, and connectivity for the Internet of Things. **Looking further ahead**, the infrastructure may be deployed, to enable the sustainable presence of humanity in space, including habitats, research facilities, in-orbit refuelling stations, and factories.

This increasing viability of space applications is enabled by disruptive changes such as decreasing launch costs, advances in miniaturisation, standardisation, and production at scale, as well as the introduction of technologies from adjacent technological fields (e.g. AI, robotics, advanced manufacturing, quantum communications).



Key uncertainties

Will the enabling technologies ever become capable enough? Will the more ambitious space applications ever become financially competitive? Will space become a field of geopolitical conflict? Will the necessary regulations for the use of space be put in place? Will there ever be a real demand for more than the practical applications of space?

Relevance / Impact

- More accurate and available positioning, navigation and timing, enables e.g. precision agriculture.
- Higher resolution Earth observation data enables advanced applications such as predictive models (with big data and AI).
- Ubiquitous and affordable communication constellations enable e.g. global internet.

Weak Signals (Proofs / Examples)

- Space suit designed by a high-fashion company.
- Development of a platform in space, to produce semiconductors, pharmaceuticals, fibre-optics.
- Use of AI methods to create Earth's digital twin based on satellite data.
- Successful testing of 3D-printed rocket engine parts.

Technological maturity



Intermediate

New materials and digital production

Technological trend 6 – Transforming how things are made

Description

New materials offer unique properties like heat resistance, energy storage, and self-healing. **Digital production** aims to digitise the entire value chain, enabling real-time monitoring and optimisation. Starting with production, it involves partners, suppliers, and users to optimise designs, processes, operations, and support.

New materials focus on **enhancing performance in various aspects** such as weight, conductivity, heat resistance, and “exotic” properties. Digital production aims to **digitise the value chain**, from concept, to manufacture, use, and disposal. **Additive manufacturing** or 3D printing is a key aspect of the digital production method creating three-dimensional objects from digital models and various materials, used e.g., for rapid prototyping or on-the-spot production.

New material technologies are driven by rapid technological advances in a wide array of materials research and development fields. Digital production advancements are driven by developments in many enabling fields.



Key uncertainties

How can the several technical challenges of 3D printing be overcome? What will be the rates of adoption for digital production methods, and what will be the balance between benefits, costs and risks? How can the challenges in terms of manufacture and scalability of many new materials be addressed?

Relevance / Impact

- Continuously improving properties of new materials enable increasingly ambitious applications, up to seemingly "unnatural" applications, e.g., metamaterials for electromagnetic cloaking.
- The digitisation of increasingly more parts of the value chain promotes technical and economic efficiency in a wide array of sectors.

Weak Signals (Proofs / Examples)

- Researchers create a non-invasive neural implant with graphene electrodes.
- Researchers achieve superconductivity at minus 23 degrees Celsius under high pressure.
- Consortium developing an “industrial metaverse”, enabling digital twins and Internet of Things applications.
- Researchers employ a unique 3D printing method to create thin, curved, and resilient concrete walls.

Technological maturity



Intermediate

Green energy and resilience

Technological trend 7 – Powering a clean and sustainable future

Description

Green or renewable energy comes from natural sources that replenish themselves faster than they're used up. These sources include solar, wind, hydropower (dams), marine (ocean-based), geothermal (underground heat), and biomass (organic materials).

Resilience in energy systems is defined as the ability to withstand threats, both natural and man-made. Green energy sources can have significant benefits to resilience, including low reliance on fuel supply and smaller, decentralised power generation.

The ultimate vision for green energy is to achieve **a low- or zero-emission economy**. This drive towards green energy comes from the need to combat climate change, improve resilience, and advancements in renewable energy technology.



Key uncertainties

What will be the net effect of the transition to green energy on the economy and on employment? How can regulations help spread the use of green energy? How will the various renewable energy technologies develop in the future?

Relevance / Impact

- Decarbonisation and electrification of sectors like manufacturing and transportation.
- Mitigation of the most severe impacts of climate change, leading to economic and social advantages and avoidance of damages.
- Decrease in the importance of fossil fuels in global (geo)politics and strengthening of energy resilience.

Weak Signals (Proofs / Examples)

- Fusion energy experiment produces more energy than it consumes.
- Startup combining artificial intelligence, meteorology, and data analysis to forecast electricity production and demand.
- India and the UK work together to establish a worldwide solar grid across 140 countries, globally linking solar producers with consumers efficiently.

Technological maturity



High

Human enhancement technologies

Technological trend 8 – Merging human and machine

Description

Human enhancement technologies can enhance human performance beyond the limit of biological potential and can include additional capabilities beyond those innate to humans.

They aim to enhance **physical** (e.g. strength, dexterity, speed and endurance), **psychological** (cognition, emotion and motivation), and **social performance** (perceive oneself as part of a group, and act as part of the team). Core human augmentation technologies include **genetic engineering** (modification of reproductive cells or cells in the grown organism), **bioinformatics** (computation and analysis with large sets of biological data), **brain interfaces** (enabling direct communication between brain and computer), and **pharmaceuticals**.

Developments are enabled by rapid parallel developments in adjacent areas (e.g. robotics, AI, nanotechnology).



Key uncertainties

How can we study the huge amount that is not known about the brain? How to balance the effects of enhancements against the risk of undesirable consequences? How can we deal with significant, legal, ethical, and social challenges?

Relevance / Impact

- Enhanced productivity through labour force enhancement and increase in quality and length of human lifespan.
- Reduced costs to deliver health care due to enabling of personalised medicine and more effective preventative interventions.
- Enabling rich human-machine interfacing and enhanced interpersonal experiences via brain interfacing.

Weak Signals (Proofs / Examples)

- Company develops a neurosurgery robot capable of implanting a low-powered implant that amplifies and digitises the brain signals for broadband speed streaming.
- Researchers develop a prosthetic arm that provides a two-way interface with the user's nervous system.
- Researchers enable paralysed patient to walk again by using two wireless implants to interpret brain signals into robotic movements.

Technological maturity



Low

Cyber technologies

Technological trend 9 – Protecting our increasingly digital living

Description

Cyberspace can be defined as the virtual space of all information technology systems linked at the data level on a global scale. **Cyber technology is the study of the hardware, software, services, data and connections that** make up the cyberspace. **Cybersecurity** focuses on protecting these elements from unintended or unauthorised access, change or destruction.

Cybersecurity technologies can be broken into **attacks and defences** (e.g. malware & attack technologies, forensics), **systems security** (e.g. cryptography, authentication & authorisation), **software and platform security** (e.g. secure coding and lifecycle security), and **infrastructure security** (e.g. network security, cyber-physical systems security).

Cyberspace is foreseen to expand in the future, as more and more virtual and physical objects, or even the human body (e.g. via brain interfaces) are added to it. The importance and sophistication of cybersecurity will also increase.



Key uncertainties

What will be the “strategic balance” between offensive and defensive cyber weapons?
How will the integration of AI affect cybersecurity methods? What will be the effects of quantum cryptography and computing and at what timescales?

Relevance / Impact

- Cybersecurity technologies have the potential to significantly enhance the development of other key technologies, by increasing trust in data and communications security.
- The cyber domain is quickly becoming a field of conflict in an increasingly unstable geopolitical environment.
- Cyber-attacks on the infrastructure of the future could have devastating effects.

Weak Signals (Proofs / Examples)

- Company develops a platform for the fast estimation of cyber risks for insurance purposes.
- The US government issues a „Space Policy Directive“ for cybersecurity in space, encouraging public and private actors to think about cybersecurity from the earliest phases of spacecraft development.
- Researchers develop method to quantitively evaluate cybersecurity methods by analysing the probability of overcoming weaknesses and stealing secret information.

Technological maturity



Intermediate

Digital communication

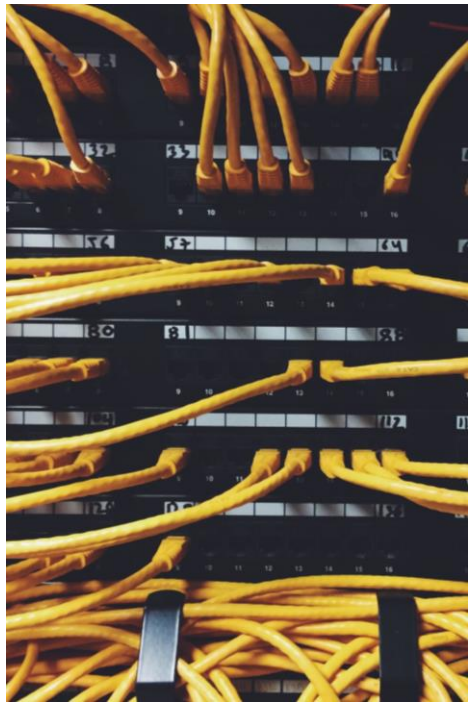
Technological trend 10 – Enhancing connectivity, enabling seamless communication globally

Description

Digital communication/connectivity encompasses digital networks, from mobile and fixed structures to the internet, including cables and satellites.

Connectivity technologies cover various types. These include **fibre optic networks**, which offer high throughput. **Wi-Fi 6** provides higher performance and security, making it suitable for industrial use. **5G/6G** mobile cellular networks are smart, reliable, scalable, and secure for a wide range of applications. **Low-power wide-area networks** are specifically designed for Internet of Things devices. **Low Earth orbit satellites** offer global coverage with relatively lower latency.

The future need for digital connectivity will have two main drivers. First, is **cloud computing**, where applications are hosted on network servers and accessed remotely. Second, the **Internet of Things**, which means adding internet connectivity to common everyday objects.



Key uncertainties

What use cases should be addressed by advanced connectivity methods (5G, 6G, space), and what use cases can be satisfied by more cost-efficient legacy approaches (e.g. 4G)? How will the capital intensiveness of some advanced connectivity methods (e.g. 5G, 6G, space) affect their economic viability?

Relevance / Impact

- Digital connectivity is a key enabler for revolutionary capabilities such as the Internet of Things, and cloud and edge computing.
- A large proportion of the global population could receive access to the internet for the first time thanks to new connectivity technologies.
- Self-driving connected vehicles packed with features could be enabled by providing high-quality network access even in remote locations.

Weak Signals (Proofs / Examples)

- Startup introduces a thin, portable modem offering fast internet anywhere.
- Auto- and telecom industry equip several vehicle models with 5G to enhance transmission speeds for improved software performance, navigation, and media streaming.
- Consortium to offer internet connectivity in rural USA and Brazil via spacecraft constellation.
- Startup is creating a VR headset with enhanced resolution and 5G connectivity, able to connect to various devices.

Technological maturity



Intermediate

Robotic and autonomous systems

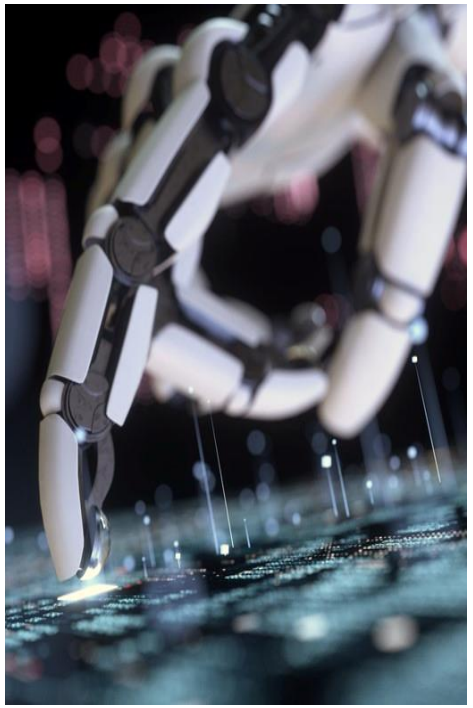
Technological trend 11 – Smart machines working for and with humans

Description

An **autonomous system** makes decisions based on the understanding of the world, itself, and the situation, responding to uncertainties. **Robotics** involves creating and developing these autonomous systems, which can range from being fully controlled by humans to operating independently.

Robotic and autonomous systems are designed to tackle tasks falling within the four D's of robotisation: **dull** (repetitive and tiring), **dirty and dangerous** (put humans at risk) and **dear** (where mistakes are costly). Depending on the mission, these systems can operate with different levels of autonomy, considering factors like technical capabilities, legal considerations, and mission requirements.

The increasing growth of robotic and autonomous systems is driven by cheaper and smaller sensors, more agile, capable, small, and cheaper actuators (turn energy into physical motion), and advances in computing, autonomy and AI.



Key uncertainties

Will the necessary very high reliability be achieved for specific applications? What is the net impact that robotic and autonomous systems will have on employment? What is the net environmental impact of robotic and autonomous systems? How can we tackle the challenges of human-robot collaboration?

Relevance / Impact

- Reduced labour costs and increased flexibility in production, such as in manufacturing and agriculture.
- Reduced risk to human workers and related costs, like in rescue operations and industrial inspections.
- Reduced human error and risk to human life, such as in medical procedures.

Weak Signals (Proofs / Examples)

- Company implements a trial system to assist with emergencies during flights.
- Startup creates and tests automated robots for building houses.
- Researchers develop and test autonomous robotic needles for medical use.
- Tech and automobile industry collaborate to introduce autonomous driving to the market.

Technological maturity



Intermediate

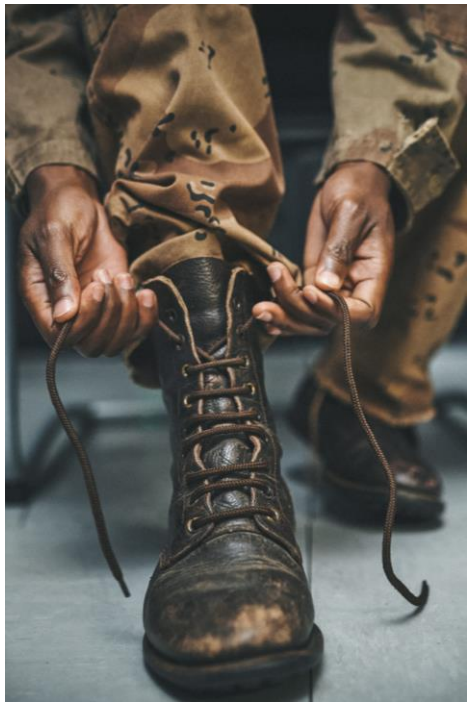
New weapons

Technological trend 12 – Applying emerging technologies to defence and military applications

Description

New weapons include a wide range of defence systems and applications that make use of or are based on the previous technology trends.

Data science and AI can enhance decision-making. **Immersive technologies** can train the soldiers of the future. **Quantum technologies** can make the oceans “transparent”. **Sensor technologies** will continue to be central to defence. **New space technologies** will be key to many defence systems, **New materials and digital production** can change how defence systems are produced. **Green energy and resilience** can make militaries energy efficient. **Human enhancement technologies** can create super soldiers. **Cyber technologies** will defend critical infrastructures. **Digital communication** will bring connectivity to novel military systems. **Robotic and autonomous systems** will perform both dull and dangerous tasks in the military. **Advanced weapons systems** will use physical effects to engage the enemy in a novel way.



Key uncertainties

Will the development of some of these technologies be economically sustainable, even for nations with large defence budgets? What is the offence/defence balance for these novel defence capabilities? How will these new technologies be integrated into existing systems? How will they be integrated into military doctrine?

Relevance / Impact

- New weapons technologies will potentially disrupt and reshape military strategies and tactics.
- The proliferation of advanced military technologies can further escalate tensions between nations, leading to arms races and security dilemmas.
- The military application of emerging technologies raises significant ethical implications.
- Investment in these technologies could fuel economic growth and technological leadership.

Weak Signals (Proofs / Examples)

- Researchers develop a quantum radar that significantly outperforms all existing classical radars.
- A defence research agency is developing an AI-powered augmented reality headset aiding army paramedics.
- Research laboratories and startups have successfully developed a system for the inexpensive conversion of conventional small aircraft for autonomous operation using a robotic arm and control unit instead of a pilot.

Technological maturity



Intermediate

Megatrends overview



Aggravating resource scarcity



Changing nature of work



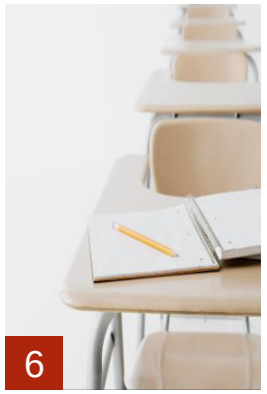
Changing security paradigm



Climate change and environmental degradation



Continuing urbanisation



Diversification of education and learning



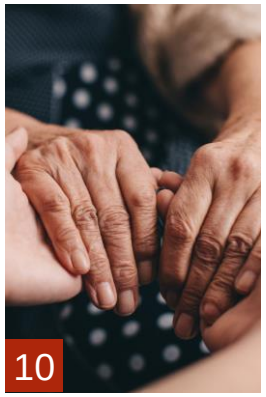
Widening inequalities



Expanding influence of East and South



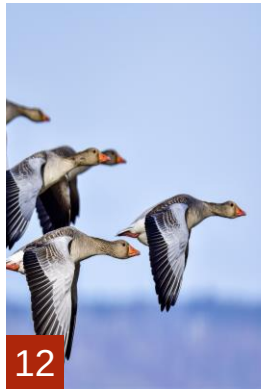
Growing consumption



Increasing demographic imbalances



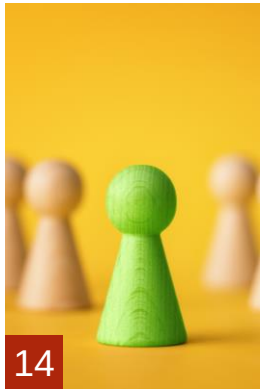
Increasing influence of new governing systems



Increasing significance of migration



Shifting health challenges



Diversity-aware society

Aggravating resource scarcity

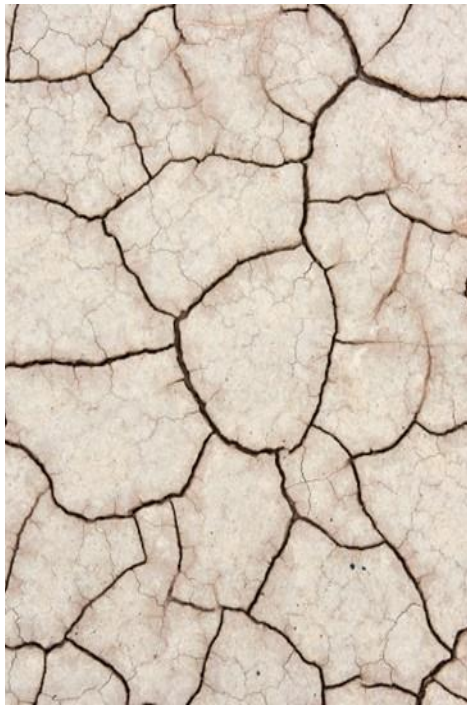
Megatrend 1 – Disconnect between human consumption and the planet's finite resources

Description

Demand for water, food, energy, land, and minerals is increasing significantly. This is causing **natural resources to become scarcer and more expensive**. This is due to several factors, including population growth, growing economies, and climate change.

The problems scarcity causes can be felt worldwide. These include water shortages, unstable food access, and energy crises. The consequences of resource scarcity are far-reaching and include environmental degradation, economic instability, and social unrest.

Addressing this megatrend requires a comprehensive approach. **Consumption behaviour change** must be encouraged. Innovative ways to manage resources more sustainably with the **use of emerging technologies** need to be established.



Key uncertainties

How will societal values evolve in response to escalating resource scarcity? What impact will technological advancements have on resource demand and availability? How will economic systems adapt to address the growing scarcity of resources? How will international governance structures evolve to manage resource challenges effectively?

Relevance / Impact

- Shifts in societal values from excess towards mindful consumption.
- Technology as a driver for circular economy, sustainable manufacturing and recycling practices.
- Resource scarcity calls for focus on sustainable business models and use of innovative materials.
- Efforts to achieve energy independence and fair global resource distribution shape geopolitical strategies.

Weak Signals (Proofs / Examples)

- Rising costs of crucial resources like water, food, and energy cause challenges for businesses and consumers.
- Rising awareness among the public about the consequences of resource scarcity.
- Businesses are increasingly focusing on Environmental, Social, and Governance factors in their operations.
- Concerns are being raised about impact of new construction projects on ecosystems and biodiversity.
- State-initiated transformation towards renewable energy.

Changing nature of work

Megatrend 2 – Upskilling and reskilling for a technology-driven workplace

Description

The world of work is undergoing a thorough transformation. New generations, **digitally native and purpose-driven**, are entering the workforce, while older generations are extending their careers. The demographic shift is changing job markets, career paths, and organisational structures. This change is also influenced by technology, globalisation, and economic uncertainties.
The **future of work is not just digital, but also purposeful**. Workers increasingly seek careers that align with their values and contribute to a positive impact. Work is becoming more **flexible and spread out**. Remote work policies are changing how we understand jobs. The **increase in freelance or gig work** is blurring the lines between having a regular job and running a business.

The **skills gap** between employers' needs and workers' qualifications is widening. To stay competitive in a labour market that is technologically advancing, **continuous upskilling and reskilling** are necessary.



Key uncertainties

What role will societal attitudes play in embracing workplace automation? How fast will technology change jobs and needed skills? How will the gig economy affect income and businesses? How will remote work and advanced technology use in labour impact the environment? What policies can balance innovation with fair labour practices?

Relevance / Impact

- Altered expectations around work-life balance call for flexible, autonomous employment models.
- Technology shapes and creates new job positions and makes up or reskilling a necessity.
- Negative impacts on labour market, state welfare system and tax revenues through the exchange of human labour for automation.

Weak Signals (Proofs / Examples)

- Increasing significance of degrees and digital skills in the job market.
- Change in remote work policies in firms and the growing demand from new generations entering the workforce.
- Growing investments in automatisation in major industries.
- Easy re- or upskilling of individuals with online learning platforms.
- Use of online platforms by individuals to offer freelance services in the sense of a gig economy.

Changing security paradigm

Megatrend 3 – Safeguarding tomorrow: Navigating the evolving security landscape

Description

The global security landscape is changing significantly. Previously focused on military threats between nations, it now includes cyber threats, climate change induced disasters, and terrorism. With the increasing frequency of security-relevant events, the perception of security among the population decreases.
Military threats are becoming hybrid, employing varied tactics. Politically motivated **cyber-attacks are on the rise**, alongside an **increasing militarisation of space**. Countries like China, Russia, and India are heavily investing in space programs, leading to more powerful players in space. Advanced technologies like artificial intelligence, big data analytics, quantum technologies, autonomous weapons, biotechnologies, and hypersonic glide vehicles are **transforming power structures and global relations**.

Geopolitical relations frequently oscillate between cooperation and competition, complicating the attainment and definition of "collective security".



Key uncertainties

How can the solidarity of a societies facing security threats be improved? How will technological advancements shape the tactics used in warfare? How will economic shifts impact defence spending? What possible disasters will be induced by climate change in the future, and how can they be prevented? How do shifting alliances influence security strategies?

Relevance / Impact

- Adjustments in societal perceptions and values regarding security.
- Necessity of maintaining technological superiority and innovation in defence strategies.
- Need for industrial resilience and self-sufficiency to mitigate vulnerabilities.
- Reshape of international relations and power dynamics as well as reassessment of alliances and geopolitical strategies.

Weak Signals (Proofs / Examples)

- State and non-state actors are actively developing and deploying advanced military technologies with increasing spending.
- Technology used in both, space exploration and military, points to blurred lines between civil and defence sectors.
- Utilisation of hybrid warfare tactics in the recent war in Ukraine.
- Almost daily incidents of cyberattacks on governmental and non-governmental entities.

Climate change and environmental degradation

Megatrend 4 – Earth on the brink, from crisis to transformation

Description

Greenhouse gas emissions and global temperatures are rising. Urgent action is needed to **mitigate the harmful impacts of climate change**. This trend encompasses a broad spectrum of challenges. These include **biodiversity loss and destroying living spaces**. It also covers extreme weather events and resulting resource scarcity.

Societal attitudes are changing because of these challenges. People now want **eco-friendly products**. They are also encouraged to make **green investments**. However, uncertainties remain regarding how well mitigation efforts work and **how severe future climate impacts will be**. These unknowns make achieving environmental resilience challenging.

Policymakers face the challenge of balancing immediate economic needs with future sustainability goals. To do this, they are using tools like **carbon pricing** and **emissions trading**. These tools are designed to encourage companies to reduce their emissions. They also aim to promote investments in sustainable production and energy supply.



Key uncertainties

Can societal values and norms evolve to prioritise sustainability? What technologies emerge to address environmental challenges? What implications has a low-carbon economy on businesses? How will ecosystems adapt to changing environmental conditions? How do geopolitical tensions impact international cooperation on climate action?

Relevance / Impact

- Economic aftermaths of transitioning to a sustainable, low-carbon economy.
- Social shifts towards eco-conscious consumer behaviour and green investments.
- Political challenges in boosting international cooperation and implementing effective climate policies.
- Environmental degradation and loss of biodiversity threaten ecosystem health and human well-being.

Weak Signals (Proofs / Examples)

- Rising frequency of extreme weather events.
- Adoption of renewable energy sources like solar and wind power on a global scale.
- Growing popularity of sustainable lifestyles, including plant-based diets and zero-waste practices.
- Implementation of carbon pricing mechanisms and emissions trading schemes in various countries.
- Development and deployment of innovative technologies for carbon capture and sustainable agriculture.

Continuing urbanisation

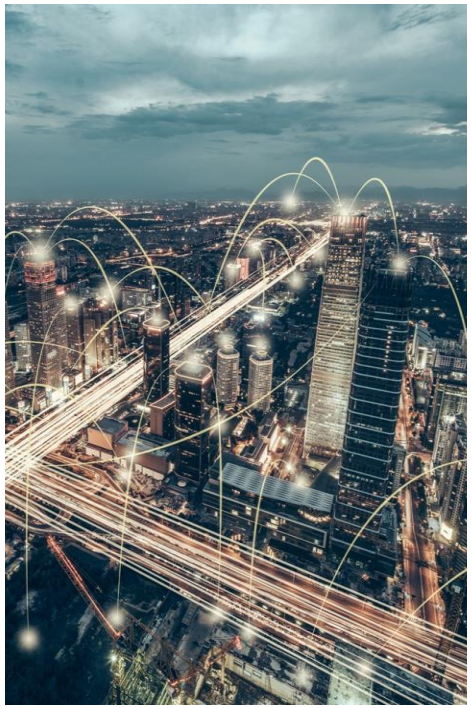
Megatrend 5 – Cityscape shift, from concrete jungles to sustainable hubs

Description

Urbanisation is the ongoing **migration of people from rural to urban areas** in search of better opportunities. This movement is transforming the global landscape. As cities continue to grow and evolve, they become **epicentres** of economic activity, innovation, and cultural exchange.

However, rapid urbanisation also poses significant challenges, including environmental degradation, social inequalities, and infrastructural strain. Cities need to make housing affordable, reduce traffic jams and ensure everyone can access vital services. Digitalisation and technological advancements offer opportunities for sustainable urban development, enabling **data-driven decision-making** and citizen engagement.

Working together is key. Local governments, communities, and global networks need to join forces. This helps meet the varied needs and goals of city residents.



Key uncertainties

Can technological innovations address environmental pressures and socioeconomic disparities? How will economic factors impact the development and affordability of urban infrastructure? How to prioritise sustainability and resilience amidst rapid urban growth? What geopolitical factors influence the trajectory of urbanisation on a global scale?

Relevance / Impact

- Environmental sustainability via clean energy and resilient infrastructure can promote economic growth and job creation in cities.
- Smart city technologies can optimise resource use, improve service delivery, and enhance disaster preparedness.
- Green spaces, availability of healthcare and education in cities unlock higher quality of life and social mobility.

Weak Signals (Proofs / Examples)

- Urban farming initiatives sprouting in abandoned spaces and promoting local food production.
- Community-driven co-housing projects offering affordable and sustainable living options.
- Smart city pilot projects testing innovative solutions for mobility, energy management and waste reduction.
- Sharing economy platforms promoting resource optimisation and shared consumption in cities.

Diversification of education and learning

Megatrend 6 – Unleashing learning potential: The traditional concept of education needs tutoring

Description

The diversification of education and learning megatrend highlights how education changes. It responds to **new generations' needs and quickly advancing technology**. This megatrend redefines the purpose and structure of **21st-century education**.

Traditional educational models are shifting towards more **personalised**, **flexible**, and **lifelong learning experiences**. This covers several areas. First, there is an increase in **informal and peer-to-peer learning**. Second, technology is becoming a bigger part of education. **Personalised learning** services fuelled by artificial intelligence and new possibilities of Virtual Reality and Augmented Reality are on the rise.

Society understands that learning new skills continuously is important. So, educational institutions are changing. They are becoming **centres for learning** instead of only knowledge providers.



Key uncertainties

What are the societal and cultural norms' impact on new educational paradigms? How is the future of learning shaped by technology? What are the economic challenges from education diversification, are disparities addressed? What is climate change's effect on education availability? What are required political policies/regulations for evolving education?

Relevance / Impact

- Fosters inclusivity and empowers individuals to pursue personalised learning paths.
- Addresses the demand for adaptable skills in a rapidly evolving job market.
- Promotes sustainability and global citizenship through environmental education initiatives.
- Requires policy frameworks that support lifelong learning and educational equity.

Weak Signals (Proofs / Examples)

- Rise of alternative education models, such as peer-to-peer learning platforms.
- Advancements in digital competence frameworks and the spread of Massive Open Online Courses.
- Increasing emphasis on socioemotional learning in educational curricula.
- Adoption of blended learning approaches combining online or immersion and traditional classroom methods.

Widening inequalities

Megatrend 7 – Bridging the gap: Socio-Economic disparities

Description

Widening inequalities highlight the **growing gap between the affluent and marginalised segments of society**, despite efforts to alleviate poverty.

These differences appear in many areas of life. They include education, employment, healthcare, and how wealth is distributed. Gender, ethnicity, social class, and where a person lives greatly affect their chances and resources. The COVID-19 pandemic has exacerbated existing inequalities, underscoring the urgency for equitable policies and interventions. **Tackling structural barriers is crucial**. It is also important to encourage social cohesion. Additionally, inclusive economic growth must be fostered. These steps are key to fighting growing inequalities.

Failure to address these disparities could jeopardise societal stability and hinder sustainable development.



Key uncertainties

How will attitudes towards inequality evolve, and will action be taken to address it? Which technology advancements worsen/improve access to wealth, education and healthcare? Which economic policies could lessen salary inequalities? How does climate change impact resource inequalities and vulnerability? How will political efforts reduce inequalities?

Relevance / Impact

- Inequalities breed unrest and instability.
- Economic growth suffers from barriers to marginalised groups in education and jobs.
- Unequal healthcare access worsens health disparities.
- Environmental degradation hits vulnerable communities the hardest.
- Political polarisation rises as disenfranchised groups demand change.

Weak Signals (Proofs / Examples)

- Grassroots movements for social justice and equity.
- Growing public discourse on income inequality and wealth distribution.
- Corporate efforts on diversity and inclusion, like Gender Pay Gap reporting and diversity quotas.
- Policy experiments tackling systemic disparities, like universal basic income trials and progressive taxation.

Expanding influence of East and South

Megatrend 8 – The rising economic powerhouses: Shifting global dynamics

Description

East and South are becoming more influential in the world economy. This marks a big change. Economic power is moving from Western countries and Japan to rising areas. These areas include **Asia, Africa, and South America**.

China, India, Indonesia, and Brazil are experiencing **strong economic growth**. This growth comes from industrialisation, technological progress, and changes in demographic trends. These developments **reshape global trade patterns**, investment flows, and geopolitical alliances.

Asia is expected to generate **more than half of the world's economic output by 2050**. This highlights the emergence of **new economic powerhouses** and a broader variety of global markets. New trade unions, like **BRICS**, try to counter the power of established Western economic forces. This leads to geopolitical tensions and difficulties in finding the right balance between competition and cooperation across country borders.



Key uncertainties

How will countries growing in influence affect societies and global trends? Who will win the technology innovation race? What is the impact of environmental challenges on emerging market growth? How will new trading unions impact economic development? What are policies for inclusive growth and reduced disparities?

Relevance / Impact

- Reshape of global economic power, creating new economic leaders.
- Altering trade patterns and boosting regional collaboration.
- Promoting innovation and infrastructure growth in emerging markets.
- Shaping and disrupting geopolitical alliances with implications for global governance.

Weak Signals (Proofs / Examples)

- Rising foreign direct investment in emerging markets, especially in infrastructure and technology.
- Increased global demand for goods and services from Asia, Africa, and South America.
- Growth of innovation hubs and tech startups boosts entrepreneurship and job creation in emerging economies.
- Growth of regional trade agreements and economic blocs, promoting intra-regional cooperation and integration.

Growing consumption

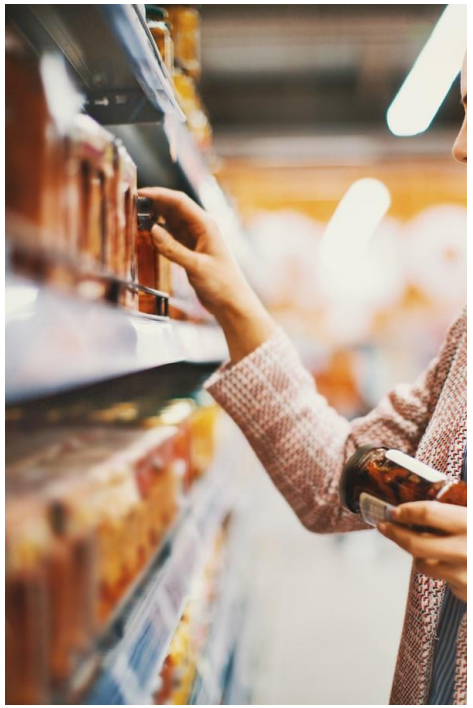
Megatrend 9 – From clicks to conscious choices

Description

Growing consumption reflects **the escalating consumption globally**. Driving factors are changes in middle-class populations, technological advancements, and shifting societal values towards sustainability. It also covers a rise in digital shopping experiences. These experiences are both personalised and immersive.

Consumers, particularly in affluent regions, are seeking **eco-friendly alternatives**. They are closely examining the environmental and social effects of what they buy. Resulting business models like shared economy, circular economy and upcycling gain in traction. Moreover, the **digital transformation of commerce** is reshaping the way businesses interact with customers, offering convenience and personalisation.

These shifts are poised to **impact traditional business models** and regulatory frameworks. It is questionable if the change in consumption behaviour mitigates the effects of the rising middle-class population in emerging countries.



Key uncertainties

How will changing societal values influence consumption? What impacts will technological advances have on (sustainable) consumption? What economic factors will impact purchasing power and spending habits? Are increasing consumption and sustainability incompatible? How will geopolitical dynamics affect supply chains and trade contracts?

Relevance / Impact

- Significant shifts towards sustainability and ethical responsibility.
- Drives innovation and economic growth of green industries, as well as shared- and circular economy possibly mitigating resource depletion.
- Impact on the need for global supply chains and trade agreements.
- Steadily rising consumption, with no turning point in sight.

Weak Signals (Proofs / Examples)

- Rise of eco-friendly brands and products in the market, by growing consumer demand for sustainable and ethically sourced goods.
- Adoption of shared and circular economy by businesses and governments.
- Shift towards purpose-driven marketing and deep engagement strategies.
- Increasing demand for personalised experiences and immersive consumer interactions.

Increasing demographic imbalances

Megatrend 10 – The demographic divide: Balancing growth and decline

Description

As the world's population burgeons towards an estimated 9.7 billion by 2050, significant **demographic imbalances** are becoming increasingly apparent.

Rapid population growth, notably in Sub-Saharan Africa, contrasts starkly with stagnation or even decline in many developed nations. This **shift in demographics** reflects intricate interplays between factors such as fertility rates, mortality rates, migration patterns, and ageing populations. Such demographic disparities are poised to **shape economies**, **societies**, and **geopolitical landscapes** in profound ways. These challenges could lead to issues such as declining youth in the workforce, sustainability concerns for pension- and health care systems, reduced family support for the elderly, and increased political influence of older demographics.

Political frameworks must ensure sustainable, inclusive futures for societies at both ends of the demographic spectrum.



Key uncertainties

Will healthcare technology mitigate effects of ageing populations? How do ageing patterns affect labour markets? How will economic policies handle regional population differences and effects? Do ageing societies influence sustainability efforts? What are the political effects of demographic imbalances on international relations and migration policies?

Relevance / Impact

- Use of new technologies for the healthcare of ageing population.
- Ageing populations strain healthcare systems and social welfare programs.
- Demographic shifts impact consumer markets and the age composition of the workforce.
- Political tensions from debates on immigration and resource allocation.

Weak Signals (Proofs / Examples)

- Emerging discussions on pension reform and healthcare financing.
- Increasing interest in workforce diversity and intergenerational equity.
- Shifts in migration policies in ageing countries highlight the need for young talents in the labour force.
- Technological innovations in healthcare and eldercare services.

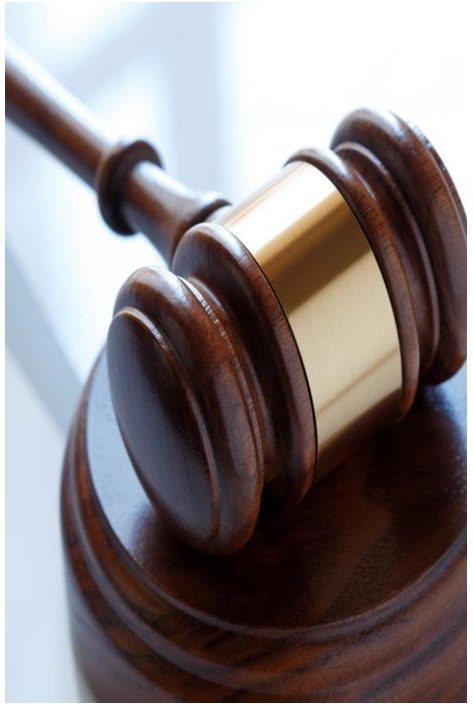
Increasing influence of new governing systems

Megatrend 11 – From top-down to grassroots: Empowering diverse voices

Description

In today's rapidly evolving world, traditional governance structures are undergoing a profound transformation. Non-state actors, fuelled by global awareness and enabled by digital platforms, are exerting **increasing influence on decision-making processes**. This shift is leading to the emergence of **multi-layered governing systems**, characterised by a diverse array of stakeholders and participatory mechanisms. The rise of **social media** has further disrupted conventional channels of communication, amplified voices and facilitated **grassroots engagement** in governance.

However, alongside these opportunities come challenges, including the **erosion of trust** in traditional institutions and the **polarisation of society**. As technology continues to advance, questions arise regarding the role of automation in decision-making and its implications for **accountability and transparency**.
Nevertheless, the trend towards new governing paradigms offers the potential for more inclusive, responsive, and effective forms of governance in the future.



Key uncertainties

Will participatory governance help to overcome socio-economic disparities and environmental degradation? Will technology enable automatic decision-making, e.g. without human involvement? What is the impact on industries reliant on old governance structures? What political dynamics shape emerging governance frameworks?

Relevance / Impact

- Empowerment of non-state actors and grassroots movements in decision-making processes.
- Disruption of traditional media and communication channels by social media platforms.
- Challenges to the legitimacy and authority of established governance institutions.
- Opportunities for greater transparency and accountability through digital technologies.
- Potential for polarisation and social fragmentation.

Weak Signals (Proofs / Examples)

- Increasing use of digital platforms for citizen engagement and activism.
- Rise of alternative forms of governance at local and regional levels.
- Adoption of automated decision-making systems.
- Growing demand for participatory democracy and collective intelligence approaches.
- Shifts in media consumption patterns towards online and social media platforms.

Increasing significance of migration

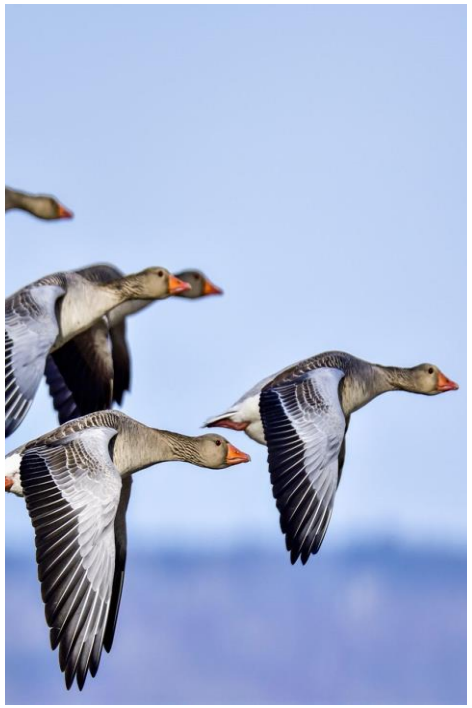
Megatrend 12 – A world on the move: From displacement to integration

Description

Migration, the movement of people across borders, has emerged as a pivotal societal and political phenomenon in an interconnected world. By 2020, over 281 million individuals were residing outside their country of birth, reflecting a significant increase since 1990.

This trend encompasses not only voluntary migration but also includes millions displaced across borders due to conflict and persecution. Migration dynamics are shaped by a myriad of factors, including **economic disparities**, **social aspirations**, and **geopolitical tensions**.

The impact of migration extends beyond demographic shifts, influencing **cultural integration**, **labour markets**, and **political discourse**. However, managing migration poses complex challenges. These vary from **border security** to **social cohesion**, requiring comprehensive and inclusive approaches.



Key uncertainties

How to handle cultural integration in diverse societies? What is the role of technology in shaping migration patterns? What are the economic implications of labour migration for both sending and receiving countries? How will climate change impact migration dynamics? What is the influence of political ideologies on migration policies?

Relevance / Impact

- Migration shapes cultural diversity and challenges social norms within host societies.
- Effects on labour markets, economic growth, and welfare systems in sender and receiver nations.
- Climate change contributes to displacement.
- Migration policies reflect political ideologies and international relations.
- Solving migration issues demands comprehensive and inclusive governance and cooperation.

Weak Signals (Proofs / Examples)

- Increasing global mobility and migration flows.
- Rising humanitarian crises and displacement events lead to migration.
- Shifts in public perceptions towards migration and migrants.
- Technological advancements facilitating communication, movement, but also surveillance.
- Geopolitical events influencing migration patterns and policy responses with increased use of border control.

Shifting health challenges

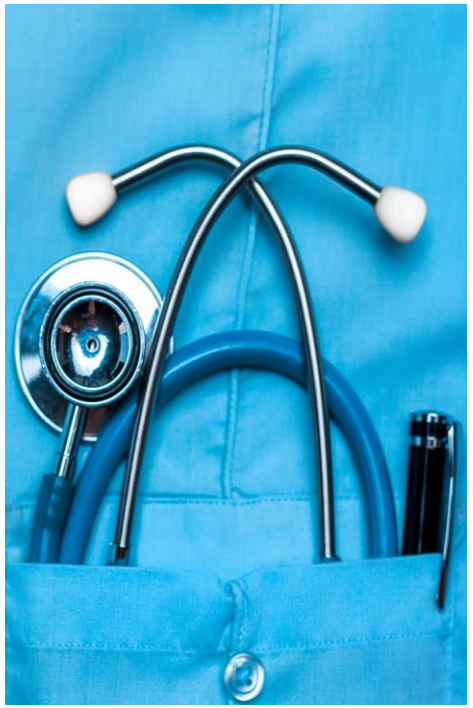
Megatrend 13 – From viral to vital: Adapting to the new norms of health challenges

Description

Health challenges are undergoing a significant shift, influenced by a combination of factors such as **advances in science**, **improved living standards**, and **environmental changes**.

Infectious diseases, once dominant, have been mitigated, but **new health burdens emerge** from unhealthy lifestyles, pollution, and other anthropogenic causes. The **ageing population**, coupled with **non-communicable diseases** like cancer and mental health issues, pose new complexities to global health. Additionally, the COVID-19 pandemic highlighted the need for better preparedness and response to emerging health threats.

Digitalisation and **personalised medicine** offer promising solutions but also raise questions about data privacy and accessibility. Advances in **CRISPR-Cas9 gene editing** could enhance humans to be unaffected by specific incurable diseases. **Nanomedicines** could autonomously target disease-relieving effects only where it is necessary.



Key uncertainties

How will societies react in the face of possible outbreaks of diseases? What ethical issues arise with use of technology in healthcare? What economic disparities will emerge due to uneven healthcare access? How does environmental decline affect human health? How will governments handle global health management amid geopolitical tensions?

Relevance / Impact

- Increasing healthcare costs due to the rising burden of non-communicable diseases.
- Greater emphasis on preventive healthcare.
- Challenges in healthcare infrastructure and workforce management.
- Heightened awareness of environmental factors influencing health.
- Need for international collaboration and policy coordination to address global health challenges.

Weak Signals (Proofs / Examples)

- Rising prevalence of obesity and mental health disorders.
- Emergence of new infectious diseases and antimicrobial resistance.
- Technological innovations in telemedicine, wearable devices, and AI diagnostics.
- Growing public interest in holistic approaches to health, e.g. physical, mental, and emotional aspects.
- Increased investment in research and development of treatments for chronic diseases.

Diversity-aware society

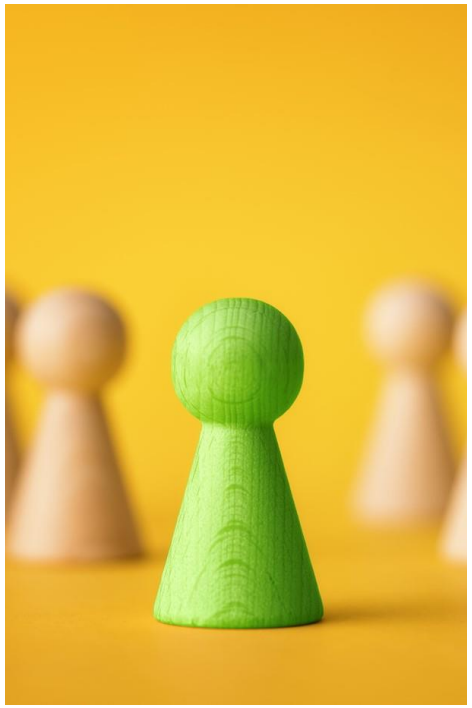
Megatrend 14 – A new era of social awareness

Description

Diversity-awareness indicates a change in society. This change means more people are speaking up. They understand social problems better and support groups with less power.

Fuelled by digital connectivity and global awareness, individuals are **asserting their identities and challenging traditional norms**. This megatrend is characterised by a growing emphasis on authenticity, inclusivity, and social justice. From grassroots activism to corporate diversity initiatives, woke culture is reshaping societal values and power dynamics. It is particularly prevalent among younger generations who prioritise empathy, equity, and social responsibility. However, the **spread of misinformation** and echo chambers challenge the authenticity of online activism.

This trend affects many areas of life. These areas include education, business practices, and governance structures. It helps create a fairer and more inclusive society.



Key uncertainties

How will political polarisation impact the progression of diversity-aware culture? How will technological advancements influence the dissemination of woke ideologies? Will diversity-aware branding lead to genuine change, or will it be perceived as superficial? How will diversity-aware culture intersect with environmental activism?

Relevance / Impact

- Social media platforms amplify marginalised voices and foster community-building.
- Businesses embracing diversity could experience improved innovation and consumer trust.
- Embracing diversity fosters social cohesion and challenges discriminatory norms.
- Policy reforms should address systemic inequalities and promote social justice.
- Individualism of opinion but also opinion-making.

Weak Signals (Proofs / Examples)

- Increased representation of marginalised groups in mainstream media and entertainment.
- Grassroots activism and social movements advocating for systemic change.
- Generation Z's embrace of identity politics and social justice causes.
- Cultural shifts towards inclusivity and acceptance of diverse perspectives.